Data acquisition

تعني تحصيل و استخلاص البيانات

senser → signal conditing circuit → A/D → computer

for TLL

	0	1
which means	0V	5V
from the range	(0 ~ 0.8)V	(2 ~ 5.5)V

for CMOS

	0	1
from the range	0V	3 ~ 18V

2018 / 3 / 19

2nd lecture

Fundamentals of Data acquisition

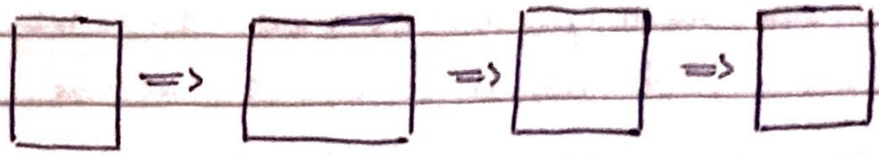
- Senser and transducer.
- Field wiring.
- Signal conditining.
- PC (controller).
- Data acquisition software.

اهم المصطلحات :

- المدى "Range"
- "Span"
- الحساسية "Sensitivity" ، "scale factor" ، "transfer function"

* Text book : Process control Instrumentation Technology
by : Curtis D. jhonson

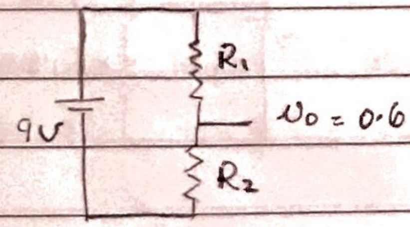
2018 / 3 / 22 3rd lecture



senser signal conditining A/D computer

For good design
- choose avilible Power supply (1.5, 4.5, 9, 6, 12) V.
- choose avilible Resistance with suitble Power (w).

Ex:



find the value of Resistance R_1 & R_2 to make $v_o = 0.6$

يستطيع تحمل
(10 ~ 20) mA

from the voltage divider rule $v_o = v_s \frac{R_2}{R_1 + R_2}$

$$0.6 = 9 \cdot \frac{R_2}{R_1 + R_2}$$

$$0.6 R_1 = (9 - 0.6) R_2 \Rightarrow R_1 = 14 R_2$$

Note نستغل ا Bridge لانه يمكننا التحكم على range
يبدأ من الصفر ، بالإضافة إلى انه يعتبر محول للإشارة,
من الـ OHM الى voltage

2018/3/26 4th lecture

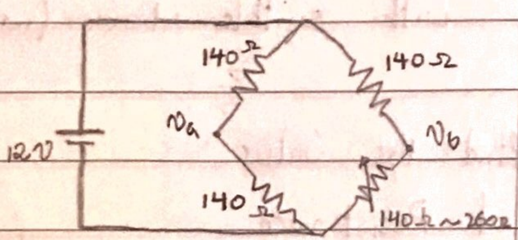
Ex: RTD with sensitivity $1.5\,\Omega/^\circ C$ and it's value at $0^\circ C = 140\,\Omega$, find the range $(0 \sim 80^\circ)$ in ohm, desing circuit to convert the range to volt

Sol:

260

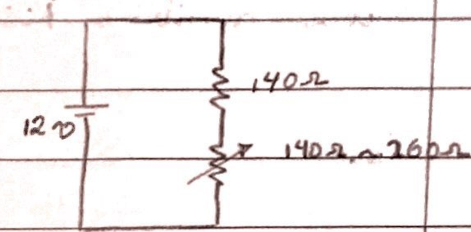
the range From 140Ω to $(140 + 1.5 * 80)\,\Omega$

Whenstan Bridge



Voltage Range from (0V ~ 1.8V)

voltage divider



Voltage Range from (6V ~ 7.8V)

$\Delta V = V_a - V_b$; $V_a = 6V$

at RTD $= 140\Omega$; $V_b = 6V$

$\Delta V = 0V$

at RTD $= 260\Omega$; $V_b = 7.8V$

$\Delta V = 1.8V$

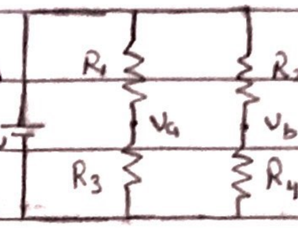
Nulling equation $R_1 R_4 = R_2 R_3$

Ex: using the resistance 130 Ω, 270 Ω using the RTD with sensitivity 1.5 Ω/°C it's value at 0°C = 140 Ω, design circuit to convert the range in voltage.

sol

use 130 Ω for R_1 & 270 Ω for R_2 and RTD for R_4

from the nulling equation



$R_3 = \dfrac{R_1 R_4}{R_2}$; where R_4 at minimum

$R_3 = 67.4074\ \Omega$

at $R_4 = 140\ \Omega$; $V_a = 4.09$ Volt , $V_b = 4.09$ V $\Delta V = 0$ V

at $R_4 = 260\ \Omega$; $V_a = 4.09$ V , $V_b = 5.88$ V $\Delta V = 1.79$ V

the Range in Voltage $(0 \sim 1.79)$ V

Ex: Pressure sensor sensitivity 0.09 V/bar and its value at 0 bar −0.2 V, Determine it output range for the Pressure $(0 \sim 140)$ bar, Design signal conditioning circuit for A/D circuit referance $(0 \sim 5)$ V

Sol:

12.4

the output range in volt from −0.2 V to $(-0.2 + 140 * 0.09)$ V

لإيجاد معادلة تربط بين V_i و V_o لتطابق الـ A/D referance

$0 = -0.2\ M + \text{offset}$

$5 = 12.4\ M + \text{offset}$; $M = 0.3968$, offset $= 0.07936$

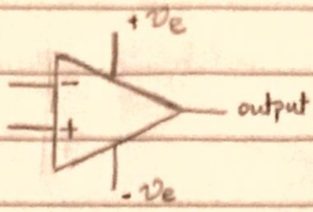
$v_o = 0.3968\, v_i + 0.07936$

نقوم بالتحقق عن طريقة الجدول كالاتي

v_i	-0.2	6.1	12.4	
v_{out}	0	2.5	5	=> should be result
	0	2.499	4.999	=> the number from the equation

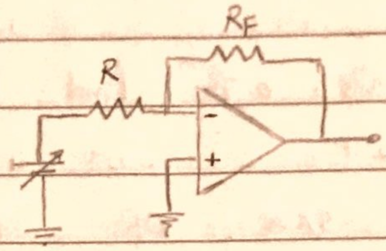
اخترنا 6.1 لانها في المنتصف بين 12.4 و -0.2

2018 / 3 / 29 5th lecture



± 15 it's means that the different between the inputs can be up to 30 volt

- inverting amplifier



v_o

حيث أنه يعطي gain بالسالب

$$\frac{v_o}{v_i} = -\frac{R_f}{R}$$

Ex: if signals $V_s = 0.8\,V$, find ($3S$, $\frac{S}{2}$, $2.5S$)

1. $R_f = 3R$ $\quad v_o = -3 * 0.8 = -2.4$

let $R_1 = 1k\Omega$

$R_f = 3k\Omega$

2. $R_f = \frac{1}{2} R_1$ $\quad v_o = -\frac{1}{2} * 0.8 = -0.4$

let $R_1 = 1k\Omega$

$R_f = 500\,\Omega$

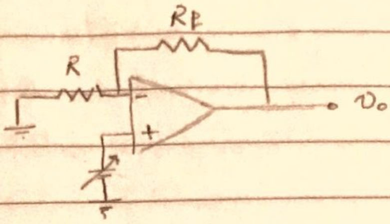
3. $R_f = 2.5 R_1$ $\quad v_o = -2.5 * 0.8 = -2$

let $R_1 = 1k\Omega$

$R_f = 2.5k\Omega$

لتخلص من ال gain السالب نقوم بعمل amplifier اخرى لإلغاء السالب

non-inverting amplifier



$$\frac{v_o}{v_i} = 1 + \frac{R_f}{R}$$

Ex: if signals $v_s = 0.75$ find 5؟

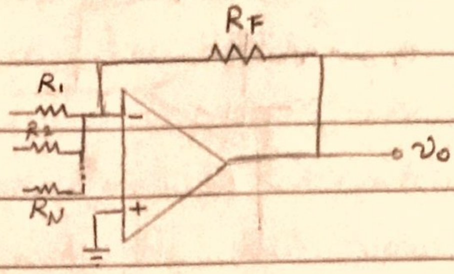
$R_1 = 1k\Omega$ so $R_f = 4k\Omega$ OR $R_1 = 3k\Omega$ so $R_F = 12k\Omega$

$v_o = (1 + 4)\, v_s = 3.75$ volt

عشان وجود ال 1+ في القانون

2018/4/12 6th lecture

Summing Amplifier



$$v_o = -\left(\frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \cdots \frac{R_f}{R_N} v_N\right)$$

Ex: $V_1 = 1.25$ volt, $V_2 = 0.67$ volt, $V_3 = 0.8$ volt

find $V_1 + V_2$, $V_1 + 2V_2$, $\frac{1}{2}V_1 + 2V_2 + 0.2V_3$, The average of them

1

$R_1 = 1k\Omega$

$R_2 = 1k\Omega$

$R_F = 1k\Omega$

$v_o = \frac{R_F}{R_1} v_1 + \frac{R_F}{R_2} v_2$

$v_o = 1.92$ volt

2

$R_1 = 1k\Omega$

$R_2 = 500\Omega$

$R_f = 1k\Omega$

$v_o = \frac{R_F}{R_1} v_1 + \frac{R_F}{R_2} v_2$

$v_o = 1.585$ volt

3

$R_1 = 500\Omega$

$R_2 = 2k\Omega$

$R_3 = 5k\Omega$

$R_F = 1k\Omega$

$v_o = \frac{R_F}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \frac{R_F}{R_3} v_3$

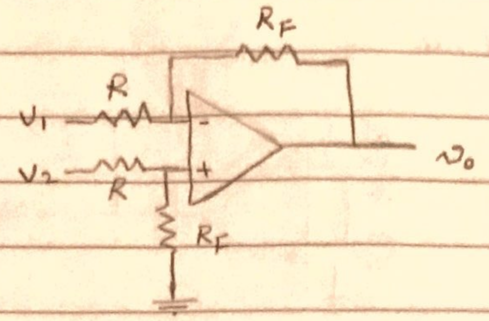
$v_o = 2.125$ volt

to find the average make the gain $\frac{1}{N}$

N: number of them

Note: to find $V_1 - V_2$ without mines make $V_2 - V_1$

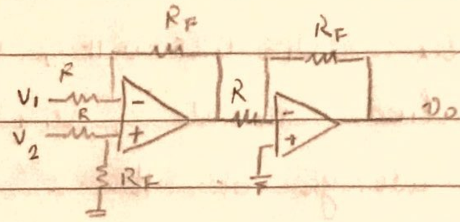
subtructor amplifier



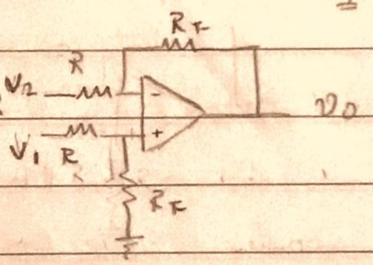
$$v_o = -\frac{R_F}{R}(V_1 - V_2) = \frac{R_F}{R}(V_2 - V_1)$$

Ex : if $V_1 = 1.25$ volt, $V_2 = 0.87$ volt find $V_1 - V_2$, $V_2 - V_1$

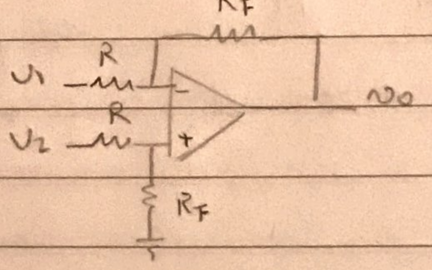
make $R_F = R$ to find $V_1 - V_2$



OR



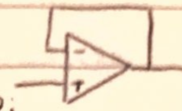
to find $V_2 - V_1$



$R_F = R$

Buffer

we use it to spert between the stages
and make more fan out



Ex: using RTD with sensivity 1.5 Ω/c in the temperature range (20° ~ 80°) and the RTD value at 0°c = 120 Ω,
- calculate its range in ohm & volt.
- Design circuit to convert the range into volt (using the Bridge)
- Design signal conditioning circuit to use (0 ~ 5) ADC

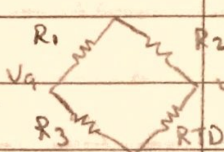
Solution:

at minimum 20° RTD = 120 + 1.5 * 20 = 150 Ω

at maximum 80° RTD = 120 + 1.5 * 80 = 240 Ω

so let R_1, R_2, R_3 = 150

and the power supply 9V



$V_a = 9 \times \frac{150}{300} = 4.5$ volt

at nulling $V_b = 9 \times \frac{150}{300} = 4.5$ volt

$\Delta V = 0$ volt

at maximum $V_b = 9 \times \frac{240}{150+240} = 5.53846$ volt

$\Delta V = -1.03846$

Range in ohm (150 ~ 240) Ω

Range in volt (0 ~ 1.038) volt

to find the signal conditioning circuit

$0 = M * 0 + \text{offset}$

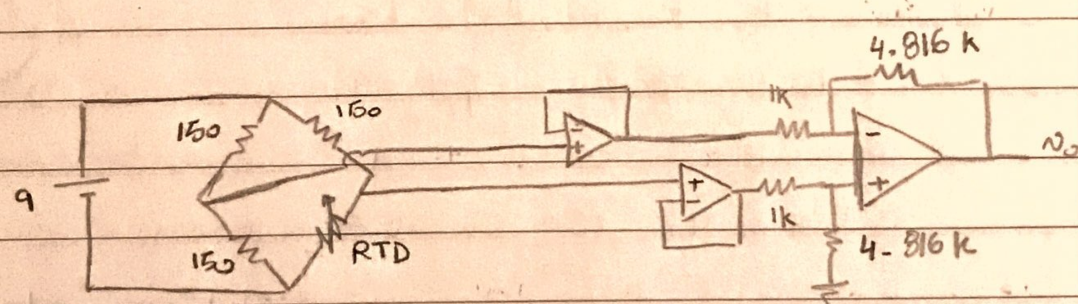
$5 = M * 1.038 + \text{offset}$

$M = 4.81695$ offset $= 0$

Vin	0	0.5016	1.038	جدول التحقيق
Vout	0	2.5	5 ...	=> should be result
Vout	0.004μ	2.416	5.002	from computer lab

using RTD = 187.635 for ΔV = 0.5016

$v_o = 4.816(v_b - v_a)$



$$v_o = -\frac{R_F}{R}(v_a - v_b)$$

$$v_o = -\frac{4.816}{1}(v_a - v_b) = 4.816(v_b - v_a).$$

2018/4/5 7^{th} lecture

Ex: using RTD with sensitivity $0.39\ \Omega/C°$ in the range (0° ~ 100°), RTD = $170\ \Omega$ at 0°C, use 9V supply, the two resistance $140\ \Omega$ & $180\ \Omega$ (using bridge)

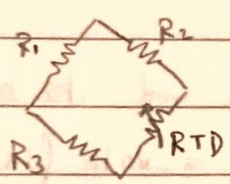
- Calculat the range in ohm & volt
- Desgin signal conditioing circuit to (0 ~ 4V) reference ADC

solution :

at minimum RTD = 170

at maximum RTD = 170 + 0.39 * 100 = 209

Range in ohm (170 ~ 209) Ω



let $R_1 = 140$, $R_2 = 180\ \Omega$ RTD = 170

so $R_3 = \frac{R_1 R_4}{R_2} = 132.22\ \Omega$

$$V_a = 9 \times \frac{R_3}{R_1 + R_3} = 4.371\ V$$

at minimum $V_b = 9 \times \frac{170}{170 + R_2} = 4.371\ V$; $\Delta V = 0$ volt

at maximum $V_b = 9 \times \frac{209}{209 + R_2} = 4.835\ V$, $\Delta V = 0.464\ V$

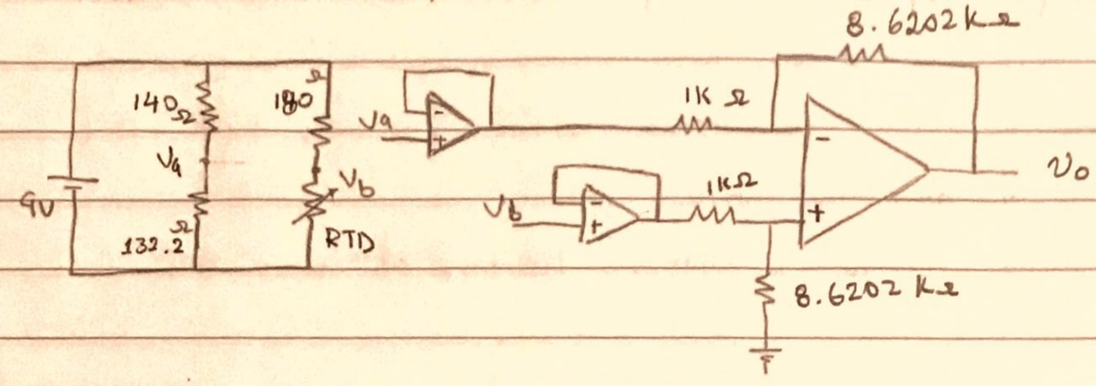
Range in Volt (0 ~ 0.464) volt

for the signal conditioning circuit

$0 = M * 0 + offset$

$4 = M * 0.464 + offset$

$M = 8.6202$, $offset = 0$



$V_o = 8.6202 \, (V_b - V_a)$

Ex: Pressure Sensor sensitivity 0.2 V/bar and its output at 0 bar = 0.8 V, calculate it's range in volt (in ± 10 bar)

- Design S.C. circuit for (0 ~ 3) voltage reference ADC

Soluation :

at minimum senser value $0.8 + 0.2 * -10 = -1.2$ Volt

at maximum senser value $0.8 + 0.2 * 10 = 2.8$ Volt

Range in volt $(-1.2 \sim 2.8)$ volt

for the S.C circuit

$0 = M * -1.2 + offset$, $M = 0.75$

$3 = M * 2.8 + offset$, $offset = 0.9$

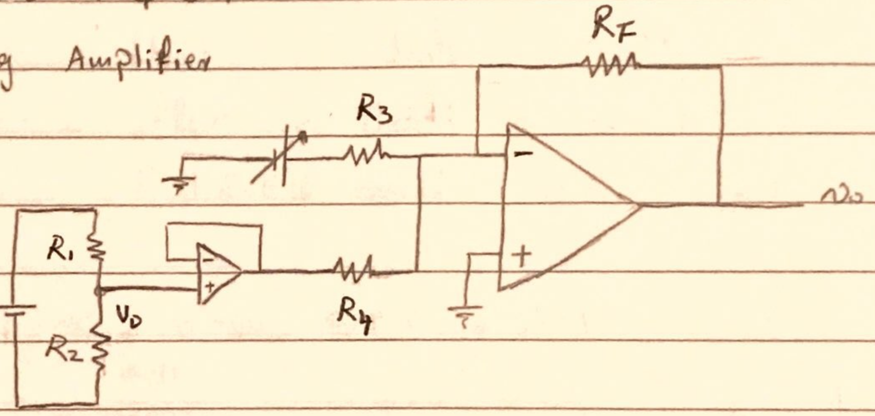
ملاحظات :

* عندما تكون بداية المدى سالبة نعوض بال offset موجب
"بالإضافة إلى أنه نتيجة ال offset تكون موجبة"
* عندما تكون بداية المدى موجبة و اكبر من صفر نعوض
بال offset سالب "كما أنه نتيجة ال offset تكون سالبة"
* في حالة "$v_o = M v_i + offset$" نستخدم Summing Amplifier
* في حالة "$v_o = M v_i - offset$" نستخدم Subtracter Amplifier
و نوصل ال offset من inverting therminal

Con. Soluation :

$$v_o = 0.75\, v_i + 0.9$$

using Summing Amplifier



0.9

$$V_D = 9 \times \frac{R_2}{R_1 + R_2} \Rightarrow R_1 = 9R_2$$

$R_4 = 0.75\, k\Omega$, $R_3 = 1 k\Omega$, $R_F = 0.75\, k\Omega$, $R_1 = 9 k\Omega$

$R_2 = 1 k\Omega$

العلاقة بين $\frac{R_F}{R_3}$ يجب ان تساوي M , $\frac{R_F}{R_4}$ تساوي 1 حتى
يدخل ال offset كما هو
نتحصل علي ال offset عن طريق مجزأ الجهد
* يجب إستعمال Buffer للفصل بين مجزأ الجهد و amplifier

Ex: Pressure senser sensitivity 0.31 V / bar and it output at 0 bar = - 0.5 V.

- calculate its output in the range ($\pm$ 12 bar).
- Design S.C. cct for (0~6) ADC voltage reference.

Solution :

minimum senser Output value $-0.5 + 0.31 * -12 = -4.22$ V

maximum senser Output value $-0.5 + 0.31 * 12 = 3.22$ V

Output range $(-4.22 \sim 3.22)$ V

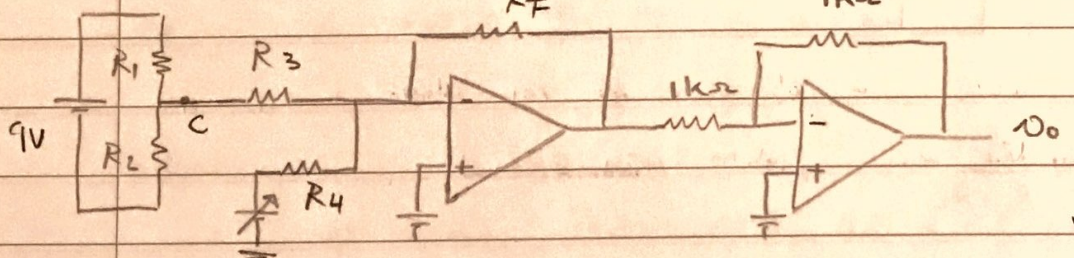
for S.C. cct

$0 = M * -4.22 + \text{offset}$

$6 = M * 3.22 + \text{offset}$

$M = 0.80645$ offset $= 3.403$

$V_o = 0.8064\, V_i + 3.403$



$\frac{R_F}{R_4} = 0.8064$ $R_F = 1k\Omega$ $R_4 = 1.24\ k\Omega$

$\frac{R_F}{R_3} = 1$ $R_3 = 1k\Omega$, at point C = 3.403V

So $\underbrace{R_1 = 1.6447\, R_2}$ $R_1 = 1.64\ k\Omega$ $R_2 = 1k\Omega$

using voltage divider Rule

2018/4/7 — 8th lecture

Ex: Pressure Senser sensitivity 0.22 V/bar and it's output at 0 bar = 0.7 V
- calculate it output in the range (0 ~ 20) bar
- Design S.C. cct for (0 ~ 6) ADC

Solution:

Output Range (0.7 ~ 0.7 + 0.22 * 20)

minimum at 0 bar

5.1 → maximum at 20 bar

for S.C. cct

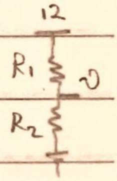
$0 = M * 0.7 + offset$

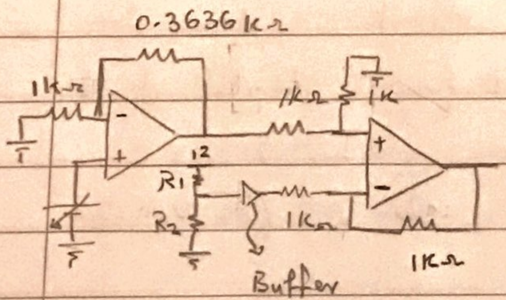
$6 = M * 5.1 + offset$

$M = 1.3636$, $offset = -0.9545$

$V_o = 1.3636\, V_i - 0.9545$

for the value of offset we can take it by the voltage divider Rule with supply 12 volt $R_1 = 11.572\, R_2$





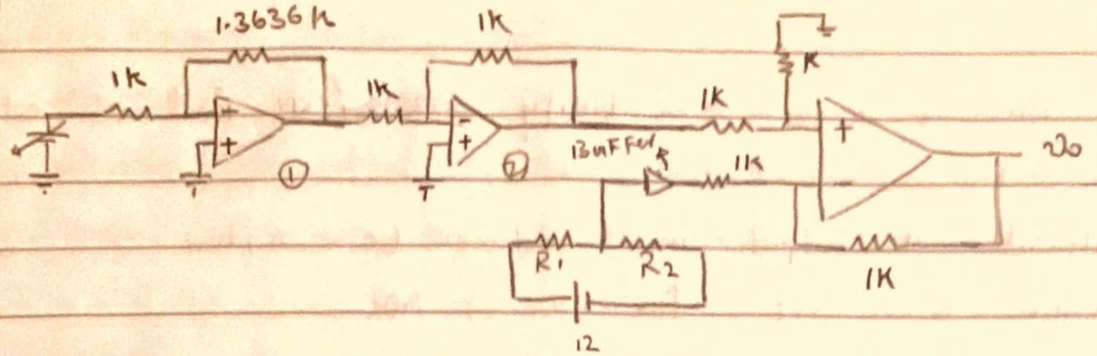
هناك ثلاثة طرق للحل

I هذه الطريقة تعتمد على الحصول على الـ gain الذي يجب أن يساوي M ثم ندخل الـ $M V_i$ على non-inverting amplifier

$V_o = \left(1 + \frac{R_F}{R}\right) V_i$ non-inverting amplifier و يجب مراعاة معادلة الـ subtractor amplifier

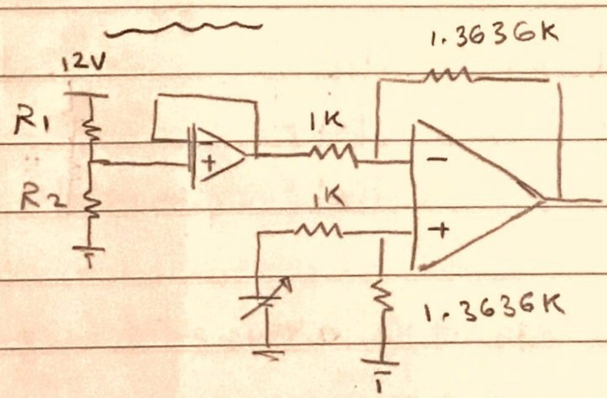
لذا نقوم بطرح واحد من M للحصول على الـ gain المطلوب

$V_o = \left(\frac{0.3636}{1} + 1\right) V_{in}$



2

في هذه الطريقة نستعمل inverting amplifier للحصول على الـ gain
$v_o = -\frac{R_F}{R} v_i$ لكن علينا مراعاة الإشارة السالبة لذا لنتخلص منها
نقوم بالضرب في gain اخرى بقيمة 1- وهو ما نتحصل عليه
من second amplifier ثم ندخلها لـ subtracter amplifier



3

في هذه الحالة نقوم باستعمال subtracter amplifier فقط ونقوم
بتغيير قيمة الـ offset لها يتناسب مع المعادلة

$$v_o = 1.3636\, v_i - 0.9545 = 1.3636\,(v_i - 0.6999)$$

حيث ندخل الـ offset بالقيمة 0.6999 وذلك عن طريق
تعديل المقاومة لتصبح $R_1 = 16.145\, R_2$

حيث $v_o = \frac{R_F}{R}(v_2 - v_1)$

ملحوظة هامة: كلما كانت الطريقة تعتمد على amplifiers أقل كلما كانت
أفضل ، لذا فالحل الثالث هو أفضل حل

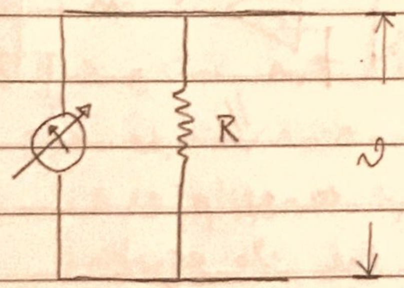
2018/4/12 9th lecture

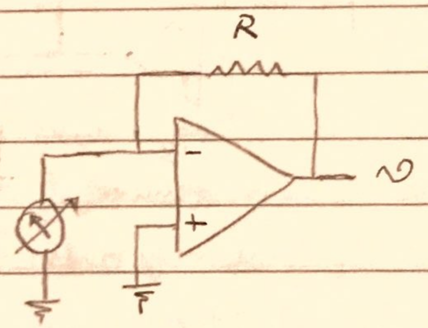
Ex: Accelerometer sensitivity 0.2 mA/g, calculate it's output range in ($\pm$ 10g)
- Design signal conditioning circuit for (0 ~ 3) ADC

Solution:

Output Range in Amper $(\overbrace{0.2m * -10}^{-2m} \sim \overbrace{0.2m * 10}^{2m})$ Amp

to convert current to voltage there is two ways





$v = R.I$

$v = -RI$

في كلا الطريقتين يجب مراعاة قيمة المقاومة لانها ستتحكم
بقيمة الـ Voltage Range

in case we choose 1KΩ
the Output Range in Volt
(-2V ~ 2V)

For example
100K Ω => $\pm$ 200V
10K Ω => $\pm$ 20V

for S.C. cct

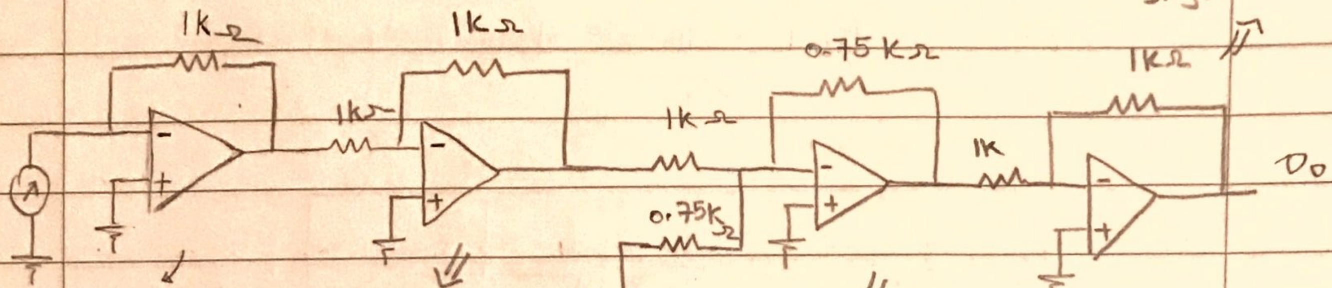
$0 = M^* -2 + \text{offset}$

$3 = M^* 2 + \text{offset}$

$M = 0.75$, $\text{offset} = 1.5$

$V_o = 0.75 V_i + 1.5$

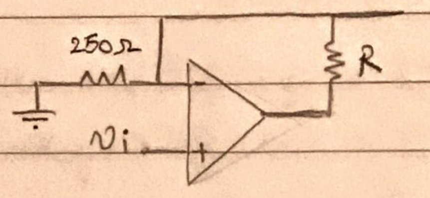
to remove the negative sign



to convert current to voltage

to remove the negative sign

to apply the Vo equation



4mA ~ 20mA transmitter has current range 4mA ~ 20mA

Voltage range (1 ~ 5)V

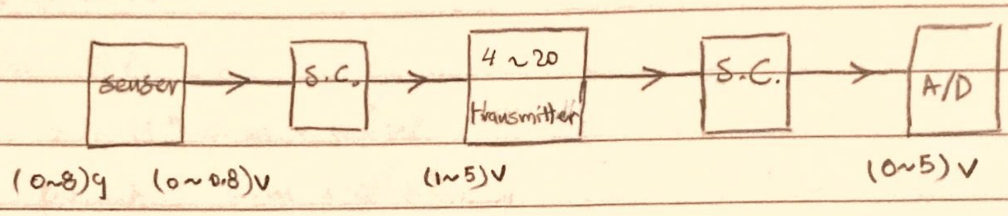
* مدى التيار يبدأ من 4mA حتى نفرق بين المجس إذا كان معطوب أو لا حيث أن 0mA تعني ان المجس معطوب و 4mA تعني ان المجس يعمل

* يجب اختيار قيمة مقاومة صغيرة حتى يعمل بشكل صحيح

Ex: Accelerometer sensitivity 0.1 v/g for the range (0~8) g
we want to send Accelerometer data for 20 m to
use it for (0~5) ADC

Solution:

Output range of the Accelerometer $(\overset{0}{0.1 * 0} \sim \overset{0.8}{0.1 * 8})$ v



transmitter circuit

لأن T. cct تقبل المدى من 1V إلى 5V و A/D تحتاج المدى من 0V
إلى 5V سنجبر لإستعمال 2 S.C. الاولى لتصفية خرج المحس
ل T.cct و الأخرى لتصفية الاشارة لدخول ل A/D.

بالنسبة ل first S.C. سنقوم بزيادة 1 فقط ليصبح
المدى من 1V إلى 1.8V و هذا المدى يقبل به ال T. cct

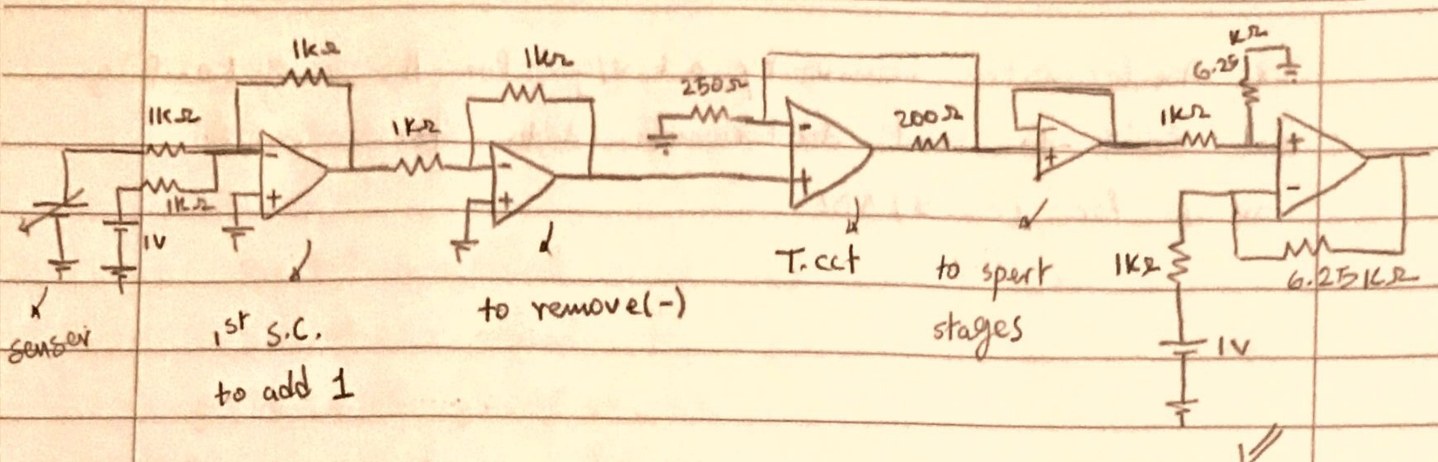
اما بالنسبة ل second S.C. سنقوم باتباع الخطوات المعتادة

$0 = M * 1 + \text{offset}$

$5 = M * 1.8 + \text{offset}$

$M = 6.25$, $\text{offset} = -6.25$

$V_o = 6.25 V_i - 6.25$



1kΩ
1kΩ
1kΩ
1kΩ
1V
sensor
1st S.C.
to add 1
1kΩ
1kΩ
to remove(-)
250Ω
T.cct
200Ω
to spert stages
6.25 kΩ
1kΩ
1kΩ
1V
6.25kΩ

$v_o = 6.25\,(v_i - 1)$

2018 / 4 / 16 10th lecture

Ex: Temperature senser sinsitivity 0.2 mV/C° in the range (0 ~ 100)°C and it's output at 0°C = 12 mV.
- Design S.C. circuit for (0 ~ 8) ADC ...
- Write the temperature equation

Soluation:

Output Range (12 mV ~ $\underbrace{12\text{ mV} + 0.2\text{m} * 100}_{32\text{ mV}}$)

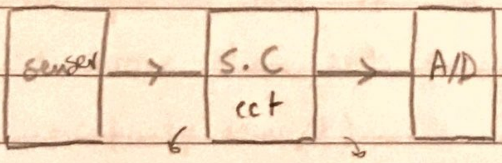
for S.C. cct

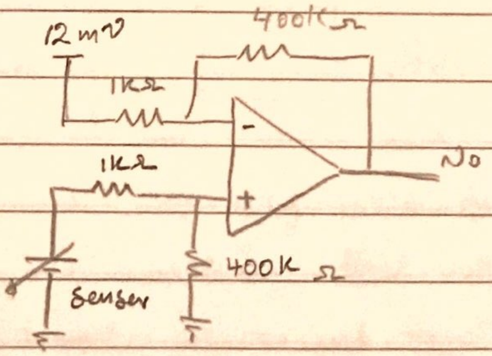
$0 = M * 12m + \text{offset}$

$8 = M * 32m + \text{offset}$

$M = 400 \quad \text{offset} = -4.8$

$V_o = 400\,V_i - 4.8 = 400(V_i - 12m)$



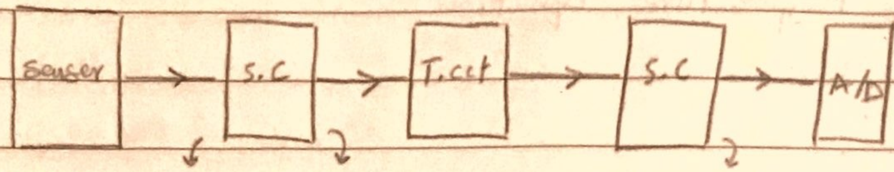


$V_i = 12m + 0.2mT \qquad V_o = 400(V_i - 12m)$

$V_o = 400(\cancel{12m} + 0.2mT - \cancel{12m})$

$V_o = 80\,mT \Rightarrow T = \dfrac{V_o}{80\,m}$

Ex: For the last example in the last lecture write acceleration equation.



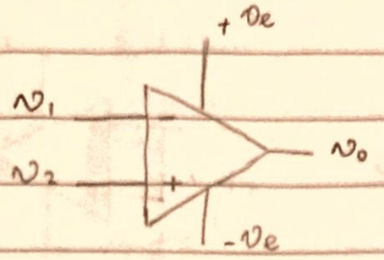
$v_i = 0.1 * A$ $\quad$ $v = v_i + 1$ $\quad$ $v_o = 6.25\, v - 6.25$

$$v_o = 6.25(v_i + 1) - 6.25 = 6.25(0.1A + 1) - 6.25$$

$$v_o = 6.25 * 0.1A + \cancel{6.25} - \cancel{6.25}$$

$$A = \frac{v_o}{0.625}$$

Comparator



when

$V_1 > V_2$

$V_o = -15$

$V_2 > V_1$

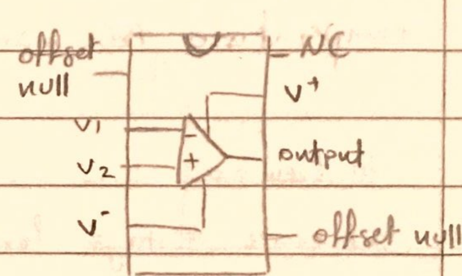
$V_o = 15$

LM 741 voltage supply

±22 volt

±18 volt

IC 8

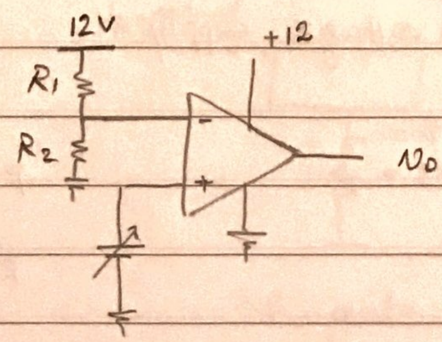


Ex: using comparator, Design circuit to operate Fan if the temperature is more than 25°C (use LM 35 sensitivity 10mV/°C)

by using poltiometer between offset null we can get zero offset

Solution

at 25°C the output of LM35 = 10m*25 = 250mV

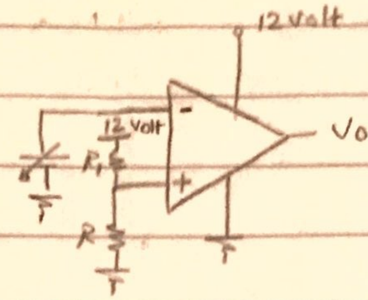


قمنا بتوصيل جهد ثابت عند ال inverting input لانه في حالة تجاوز هذا الجهد ال non-inverting input سيكون خرج المقارن موجب مما يشغل ال Fan

$R_1 = 47 R_2$

Ex: using comparator, Design circuit to operate Heater if the temperature is less than 18°c (Temp. sensor sensitivity 8mV/°C)

Reference voltage $18 * 8m = 144 mV$



نقوم بتوصيل الحساس بالـ V_1 لأنه عندما تكون أقل من V_2 سيكون الخرج موجب "كأن V_2 اكبر من V_1"

$R_1 = 82.33 R_2$

Ex: using compartor, Design circuit to operate Heater if temperature is less than 18°c and operate fan if temperature is more than 30°c (senser sensitivity 5mV/°C)

Soluation

Reference voltage for 18°c = 90 mV

Reference voltage for 30° = 150 mV

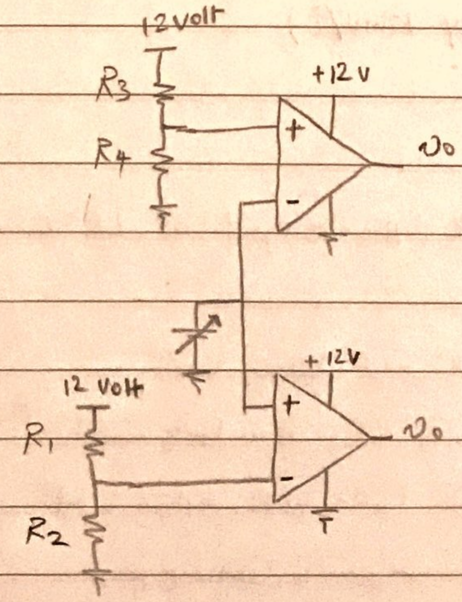
for 18°c

$R_1 = 132.3 R_2$

for 30°C

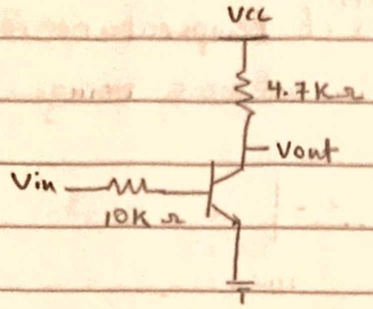
$R_3 = 79 R_4$

to 12 voltage supply

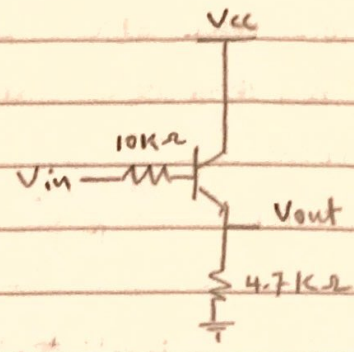


2018/4/23

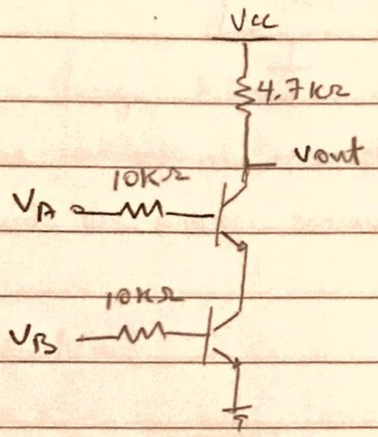
12th lecture



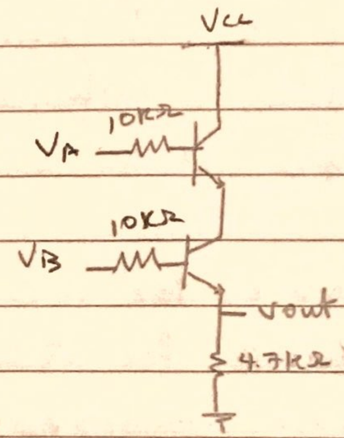
Not gate



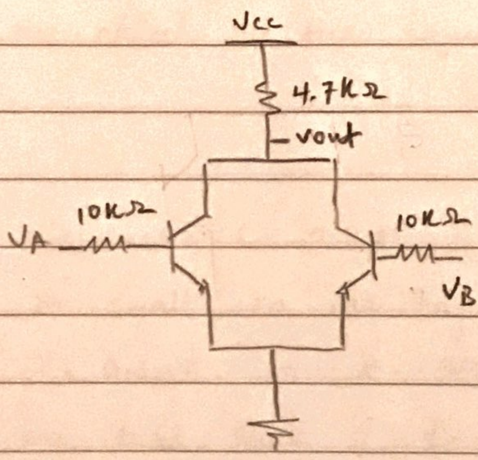
Buffer gate



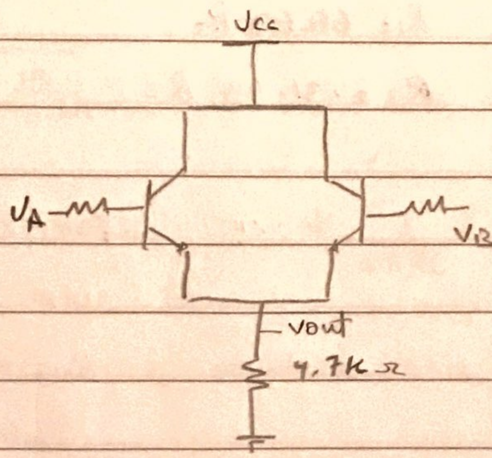
NAND gate



AND gate

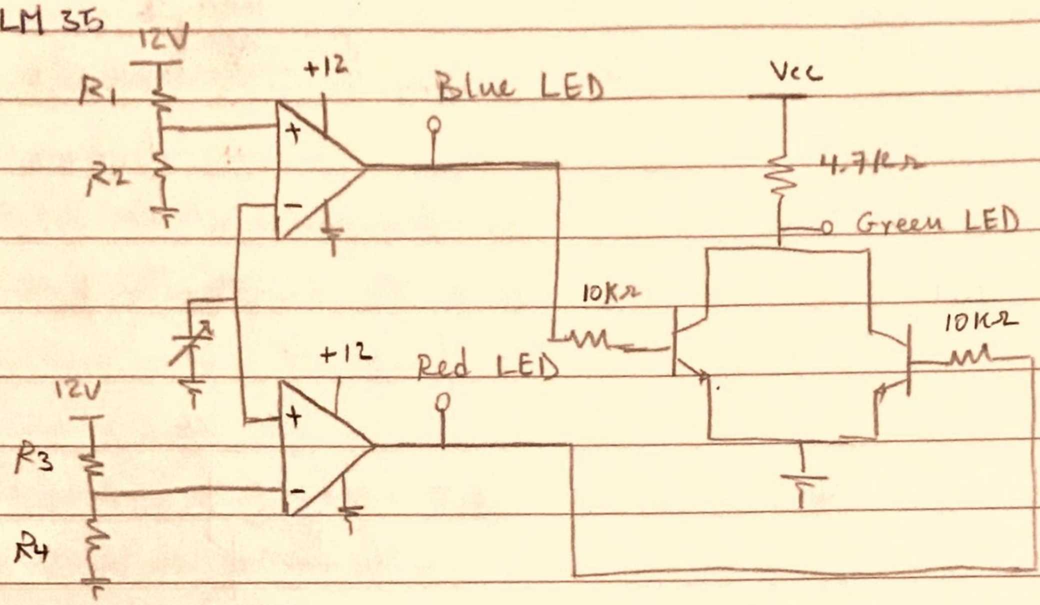


NOR gate



OR gate

Ex: Design circuit operate Red LED if Temperature is more than 37°C and operate blue LED if temperature is less than 15°C and Green LED in between using LM 35



Reference for 18°C = 180 mV

Reference for 37°C = 370 mV

for voltage supply 12 volt

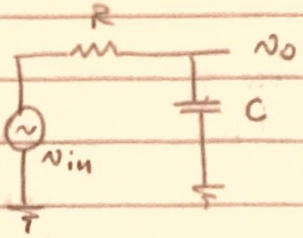
$R_1 = 65.67\, R_2$

$R_3 = 31.43\, R_2$

Filters

Low Pass Filter

$$f_c = \frac{1}{2\pi RC}$$



$$\frac{V_o}{V_i} = \frac{1}{\sqrt{1 + \left(\frac{f}{f_c}\right)^2}}$$

Ex: Design Filter to attenuate the noise to 1% and calculate the effect of the filter on the signal if the signal = 5V (1kHz) and the noise = 200mV (320kHz)

Solution

$$1\% = \frac{1}{\sqrt{1 + \left(\frac{320k}{f_c}\right)^2}} \Rightarrow f_c = 3.2\,kHz$$

the effect on the signal $\frac{1}{\sqrt{1 + \frac{1k}{3.2k}}} = 95.4\%$

assume $C = 2.2\mu F$ so $R = 22.607\Omega$ $\quad f_c = \frac{1}{2\pi RC}$

to small so we try another value

$C = 0.1\mu F$ so $R = 497.35\Omega$ dosen't a standard value

we take 510Ω $\quad f_c = 3.202\,kHz$

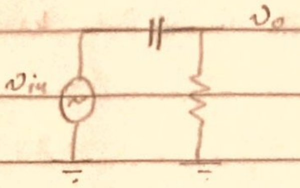
the effect on the noise became 1.00057%

* Filter make some delay

2018/5/14 14th leature

High Pass Filter

$$\frac{v_o}{v_i} = \frac{F_s/F_c}{\sqrt{1+\left(\frac{F_s}{F_c}\right)^2}}$$



Ex: Design filter to attenuate 50HZ noise signal from the required 4 KHz signal.

Soluation

if we want to attenuate the noise 1%

$$0.1\% = \frac{50/F_c}{\sqrt{1+\left(\frac{50}{f_c}\right)^2}} \Rightarrow F_c = 4.9\,KHz$$

the attanuation on the required signal = 63.23%

this value is not good so we try another value

for 5% attenuated in the noise siegnal

$$5\% = \frac{50/F_c}{\sqrt{1+\left(\frac{50}{F_c}\right)^2}} \Rightarrow F_c = 998.7\,Hz$$

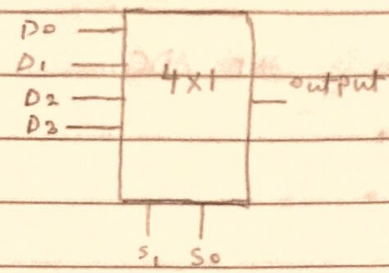
the attenuation on the required signal = 97.02%

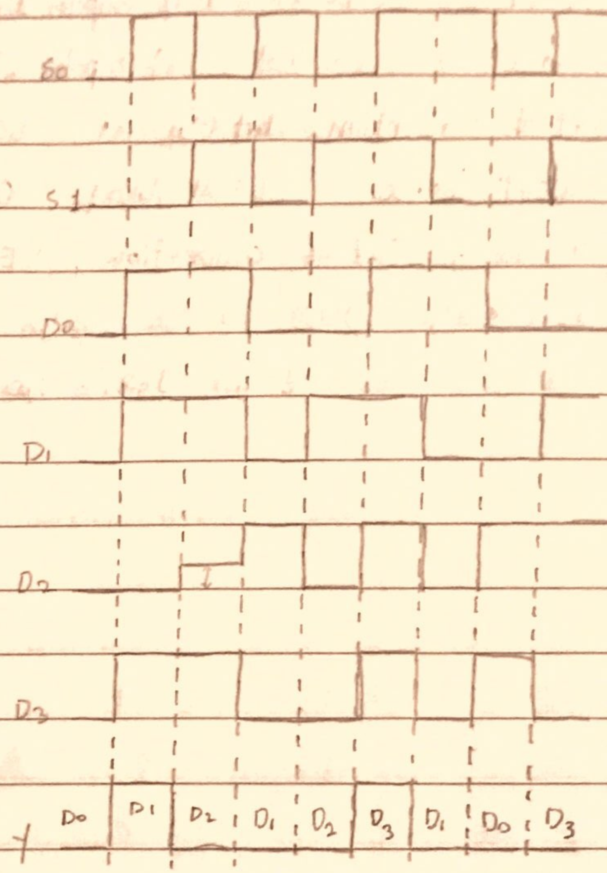
for 10% attenuate on the noise

Fc = 497.4 Hz

and the attenuation on the required signal = 99%

* Multiplexer





Digital Mux

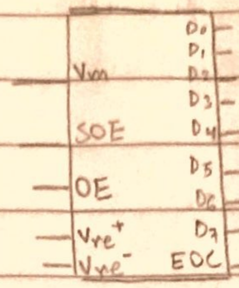
ملاحظة: تتم تسمية الـ Multiplexer بعدد الـ input و الـ output ولا يتم ذكر الـ selection

لماذا نستعمل الـ Multiplexer ؟

- يوفر S.C. cct. حيث أنه لو هناك أكثر من sensor من نفس النوع نقوم بتوصيلهم بال Multiplexer و الـ output ندخله كـ input للـ S.C. cct.

* Analog to Digital converter

* Vin = Vm



8bit ADC

* V_{re}^{+-} هو الحد الادني والأعلى للإشارة
مثلا unipoler (احادي القطبية): (0 ~ 5) او (-5 ~ 0)
أو Bipoler (ثنائي القطبية): (± 2) او (± 5)
* SOC : امر بداية التحويل start of convention
* OE : إظهار البيانات Output Enable
* EOC : End of convention و هذا ال Flag
تتم مراقبته من قبل المعالج مراقبة شديدة
هل هو مشغول أو لا

* Analog to Digital converter :

Resolution (ΔV) : أقل قيمة لدخل يستشعرها المحول لزيادة بمقدار 1 bit

$$\Delta V = \frac{\text{Voltage reference}}{2^N} = \frac{V_{ref}^{+} - V_{ref}^{-}}{2^N}$$

حيث N : عدد المخارج --

ملاحظة : كلما صغرت ΔV اصبح A/D أدق

Ex: unipoler Vref (10 ~ 0) with 4-bit output.

$$\Delta V = \frac{10-0}{2^4} = 0.625$$

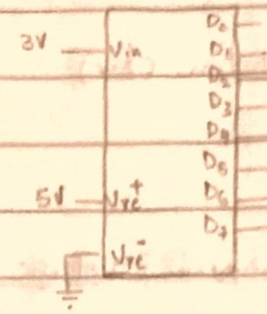
$$\text{Digital Output} = \frac{\text{Analog input}}{\Delta V} \Rightarrow \text{for unipoler}$$

Ex: if input 5V , 10V with the same A/D what is the Digital Output.

$$\text{Digital output} = \frac{\text{Analog input}}{\Delta V} = \frac{5}{0.625} = 8 = 1000$$

$$\text{Digital output} = \frac{10}{0.625} = 16$$ which is not valid value because the Maximum value 15

Ex: What is the output of the following ADC, and what is the analog input value if digital output is $(A7)_H$



Solution:

$\Delta V = \frac{5-0}{2^8} = 19.53\ mV.$

Digital output $= \frac{3}{19.53m} = 153.8 = 153 \pm 1$

$(10011001)_B$

Digital Output $(A7)_H = (167)_{10}$

Analog input = Digital output . ΔV = 3.26 V

Ex: temperature sensor sinstivity $0.8mV/C^\circ$ in the range $(0 \sim 60^\circ C)$ and it's output value at $0^\circ C$ = 0.75V.
Design S.C. cct. for $(0 \sim 5)$ V ADC and what is the temperature final equation.

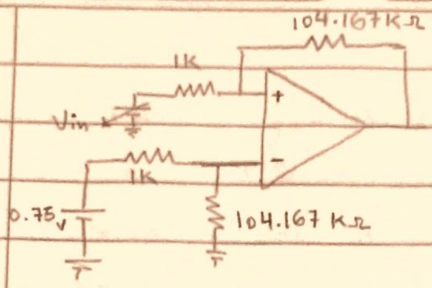
Solution:

Output sensor range $(0.75 \sim 0.75 + 0.8m * 60)$ = 0.798

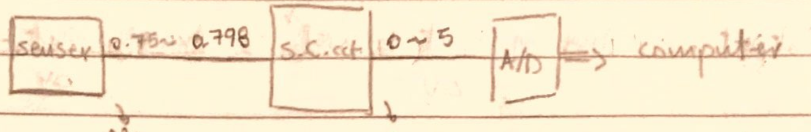
$0 = 0.75 * M + \text{offset}$ $\quad M = 104.1667$

$5 = 0.798 * M + \text{offset}$ $\quad \text{offset} = -78.125$

$V_o = 104.167\ V_i - 78.125 = V_o = 104.167\,(V_i - 0.75).$



Signal Conditionation circuit



$v_i = (0.75 + 0.8mT)$

$v_o = 104.167(v_i - 0.75)$

Digital output = $\frac{v_o}{\Delta V}$

$$\text{Digital output} = \frac{v_o}{\Delta V} = \frac{104.167(v_i - 0.75)}{\Delta V} = \frac{104.167((\cancel{0.75} + 0.8m * T) - \cancel{0.75})}{\Delta V}$$

$$T = \frac{\text{Digital output} * \Delta V}{0.8m * 104.167}$$

2018/5/21

16^{th} lecture

Analog to Digital "bipoler"

$$\Delta V = \frac{V_{ref}^{+} - V_{ref}^{-}}{2^{N}}$$

$$\text{Digital Output} = \frac{\text{Analog input} + V_{ref}^{+}}{\Delta V} = \frac{\text{Analog input} - V_{ref}^{-}}{\Delta V}$$

Ex: for Bipoler ADC with Vref ± 3V , Vin 1.5V , 8-bit output what is the Digital output

$$\Delta V = \frac{3-(-3)}{2^{8}} = 23.4375 \text{ mV}$$

$$\text{Digital Output} = \frac{1.5+3}{23.4375\text{m}} = 192 \quad (1100\ 0000)_B$$

Ex: for Bipoler ADC with ±3V and 8bit Output what is the Digital output for the input 0V

$$\Delta V = \frac{3-(-3)}{2^{8}} = 23.4375 \text{ mV}$$

$$\text{Digital Output} = \frac{0+3}{\Delta V} = 128 \quad (1000\ 0000)_B$$

Ex: Using an accelerometer which sensitivity 10 mV/g in the range ± 20 g, Design S.C. cct. for ADC which reference ±5 V with 8-bit output, what is the ADC output at 3g, -7g, what is the acceleration equation for this circuit

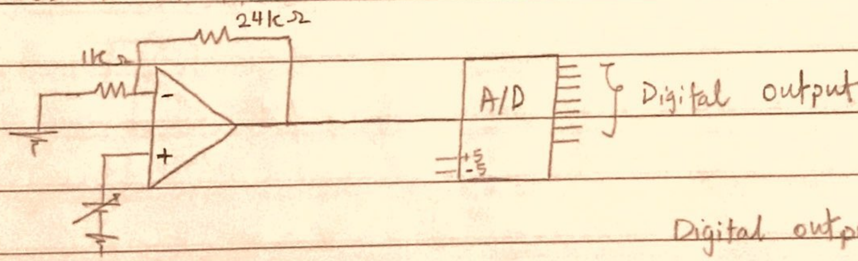
Soluation:

Sensor output range ($\underset{-200\ mV}{-20 * 10\ mV}$ ~ $\underset{200\ mV}{20 * 10\ mV}$)

$-5 = -200\ m\ M + \text{offset}$ $\qquad M = 25$

$5 = 200\ m\ M + \text{offset}$ $\qquad \text{offset} = 0$

$V_o = 25\ V_i$



Digital output = $\frac{\text{Analog} + 5}{\Delta V}$

$$V_o = \left(1 + \frac{R_F}{R}\right) V_i$$

$$\Delta V = \frac{5-(-5)}{2^8} = 39.0625\ mV$$

Acceleration	3g	-7g
$V_i = A * 10m$	30 mV	-70 mV
V_o	0.75 V	-1.75 V
Digital output	147.2 ≈ 147	83.2 ≈ 83
	$(1001\ 0011)_B$	$(0101\ 0011)_B$

$$\boxed{\text{Sensor}} \xrightarrow[= Acc * 10m]{V_i} \boxed{\text{S.C.cct}} \xrightarrow[= 25V_i]{V_o} \boxed{\text{A/D}} \to \text{Digital output} = \frac{V_o + 5}{39.0625m}$$

$$\text{Digital output} = \frac{V_o + 5}{39.0625m} = \frac{25V_i + 5}{39.0625m} = \frac{25 * 10m * Acc + 5}{39.0625m}$$

$$Acc = \frac{(\text{Digital output} * 39.0625m) - 5}{25 * 10m}$$

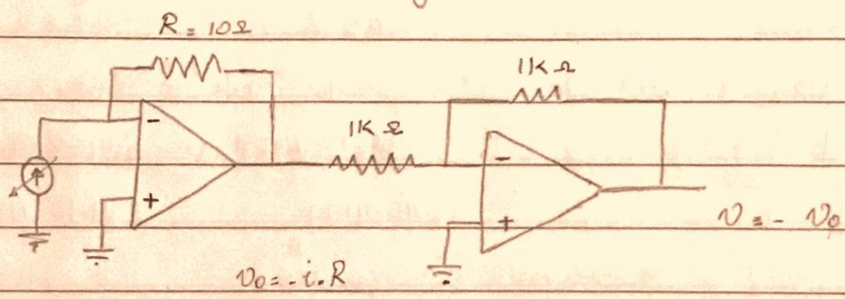
2018/5/24 17th lecture

Ex : Using barometer which sensitivity 10mA/bar and it's output at zero bar is 25 mA , Design S.C. cct. for the range ± 10 bar and using ADC (V_{ref} ± 2V), what is the digital output of ADC at -2bar , + 3.5 bar , what is the pressure equation will using in the program.

Soluation :

$$\text{Sensor Range Output } \underbrace{(25m + -10 \times 10m)}_{-75 mA} \sim \underbrace{(25m + 10 \times 10m)}_{125 mA}$$

first convert current to voltage



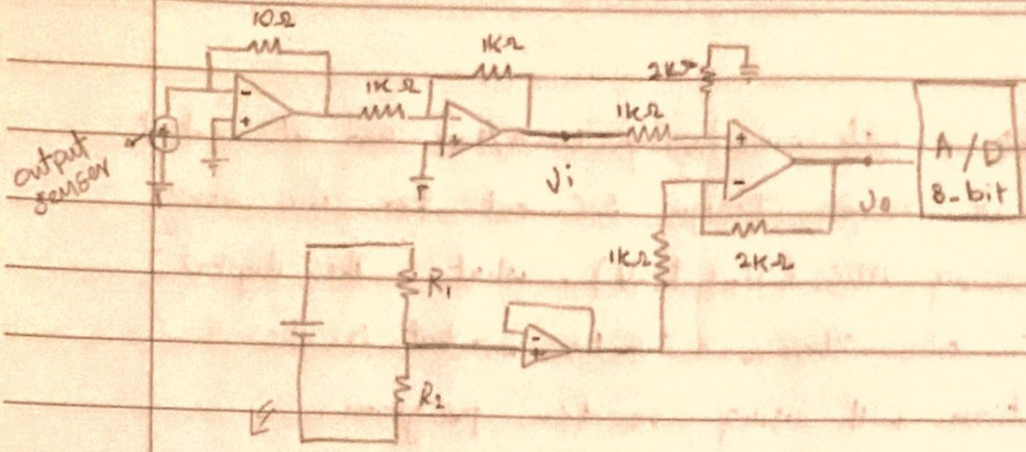
so the Output Range now will be (- 0.75 ~ 1.25) V

then the S.C. cct

$-2 = -0.75\ M + offset$ $M = 2$

$2 = 1.25\ M + offset$ $offset = -0.5$

$V_o = 2V_i - 0.5 = 2(V_i - 0.25)$

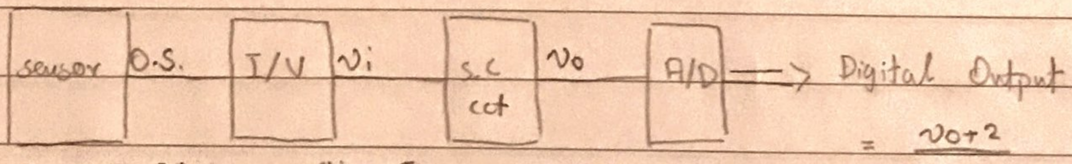


$$0.25 = 3 \times \frac{R_2}{R_1 + R_2} \Rightarrow R_1 = 11 R_2$$

Prusser	-2 bar	3.5 bar
Output sensor (25 m + 10m * P)	5 mV	60 mV
v_i (O.S. * 10)	0.05 V	0.6 V
v_o ($2v_i - 0.5$)	-0.4	0.7
Digital output ($\frac{v_o + 2}{\Delta V}$)	102.4 ≈ 102	172.8 ≈ 173
	$(0110\,0110)_B$	$(1010\,1101)_B$

$$\Delta V = \frac{2 - (-2)}{2^8} = 15.625 \text{ mV}$$

Now the equation



$= \frac{v_o + 2}{\Delta V}$

$I = 25m + P * 10m$ $\quad v_i = 10 I$ $\quad v_o = 2v_i - 0.5$

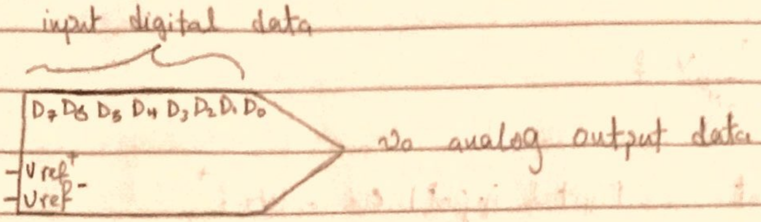
$$\text{Digital output} = \frac{v_o + 2}{\Delta V} = \frac{2v_i - 0.5 + 2}{\Delta V} = \frac{20I - 0.5 + 2}{\Delta V} =$$

$$= \frac{\cancel{0.5} + 0.2P \cancel{- 0.5} + 2}{\Delta V}$$

$$P = \frac{\text{Digital Output} * \Delta V - 2}{0.2}$$

2018/3/28 18th lecture

* Digital to analog (DAC)



For unipoler

$\Delta V = \frac{V_{ref}}{2^{N}}$ → number of input bits

analog output = Digital input * ΔV

Ex: what is the analog value of the Digital input $(01010101)_B$ with the Vref (0~4)

$(85)_D$

$\Delta V = \frac{4}{2^8} = 15.625 \text{ mV}$

Analog value = 85 * ΔV ≈ 1.328 V

Ex: for the DAC with 8-bit input and Vref (0~4) what is the value of digital input if the analog value 2.35 V?

Digital input = $\frac{\text{Analog Output}}{\Delta V} = \frac{2.35}{15.625} = 150.4 \approx 150$

$(10010110)_B$

For bipolar

$$\Delta V = \frac{V_{ref}^{+} - V_{ref}^{-}}{2^N}$$

Analog output = Digital input ΔV - V_{ref}^{+}

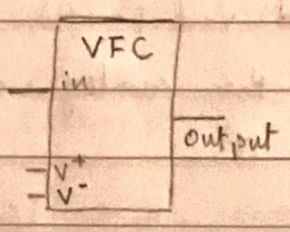
Ex: what is the analog value for DAC with 8-bit input and ±3 Vref of the following 0111 1000, 0000 1100, 1010 0000

$$\Delta V = \frac{6}{2^8} = 23.4375 mV$$

Analog output = (ΔV * Digital input) - 3

Binary Digital input	0111 1000	0000 1100	1010 0000
Decimal Digital input	120	12	160
Analog output	-0.1875	-2.71875	0.75

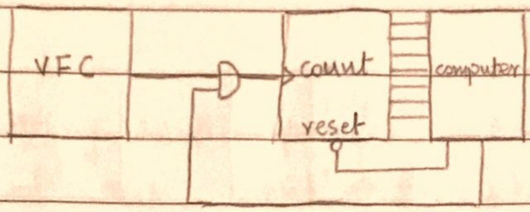
* Voltage to frequency converter (VFC)



the output is pulses

Ex: if VFC has 1KHz/V what is the output if the input 1.25 V

Output = 1.25 V * 1KHz/V = 1250 Hz



نستعمل ال reset لتصفير ال counter لانه تراكمي يقوم بتجميع القراءات معاً و لتحديد زمن الدورة الواحدة

Ex: if VFC has 1KHz/V with T = 0.2 S and input 3V, what is the counter output ?

VFC output = 3 V × 1KHz/V = 3000 Hz

counter output = 3000 HZ * 0.2 $\frac{1}{HZ}$ = 600

ملاحظة: البعض يعتقد أن هذه الدائرة هيا أفضل في التحويل من Analog إلى Digital

Ex: if counter output = 150 what is the input if T = 0.2 S and VFC has 1KHZ/V

counter input = $\frac{150}{0.2}$ = 750 HZ

VFC input = $\frac{750\ HZ}{1000\ HZ/V}$ = 0.75 Volt

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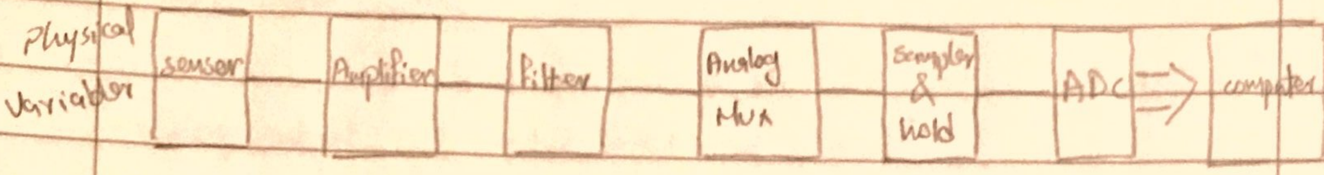
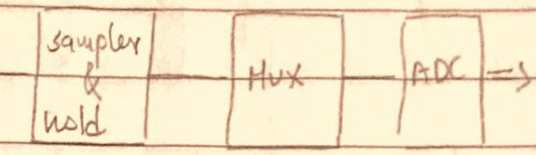
19th lecture

Data acquistion and conversion





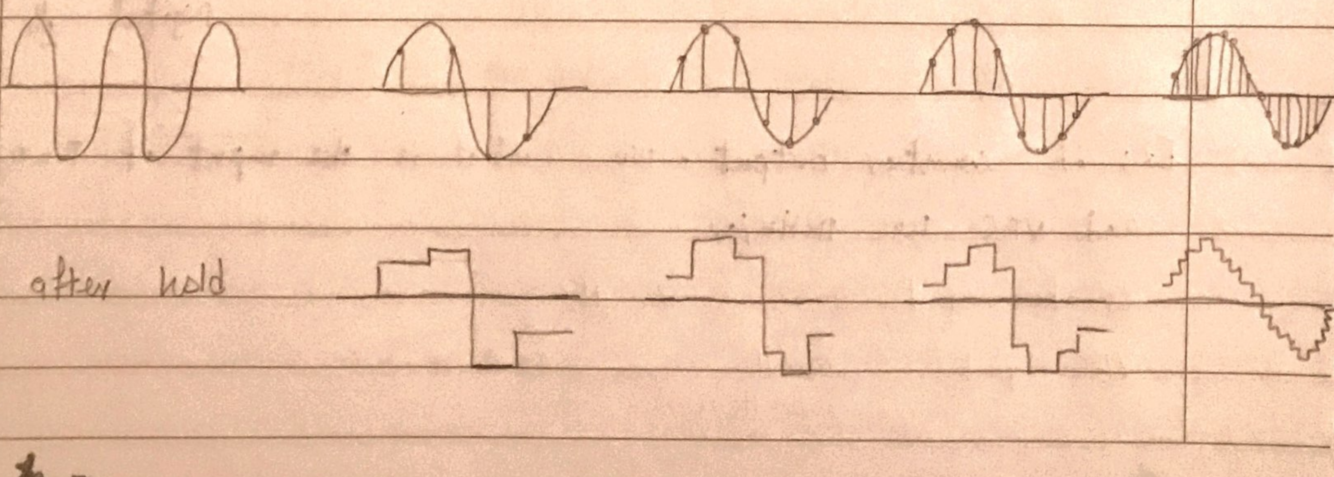
ADC conversion time : الزمن الذي يستغرقه ADC لتحويل

Sampler rate : معدل التحويل

↳ one of the most critical factors when selecting an bond sampling rate (speed), for example 1K sample.

The sampling rate is a measure of how rapidly the ADC Board can scan the input channel and identify the discrete value of signal present with respect to reference signal

cycle = Time for sampler



if the sampling rate is too slow, then a completly different waveform of lower frequency is constructed from the data recquired, this effect is called aliasing. To avoid aliasing it's necessary that the sampler rate is be at least twice of the highest expected frequency input.

Over Sampling : will provide a true picture of time course of the eventbeing studied but too much over sampling will result in very large data file.

* Sensor :

Thermal sensors

Relative temperature Scale

$T(C^\circ) = T(K^\circ) - 273.15$

$T(F^\circ) = T(R^\circ) - 459.6$

$T(F^\circ) = \frac{9}{5} T(C^\circ) + 32$

R: Rankine , K: kelven , F: Fahrenhiet , C: Ceiac

Ex: Amatenal has temperature of 335°K Find the temperature in R°

$T(C^\circ) = T(K^\circ) - 273.15 \Rightarrow T(C^\circ) = 61.85$

$T(F^\circ) = \frac{9}{5} T(C^\circ) + 32 \Rightarrow T(F^\circ) = 143.33$

$T(R^\circ) = T(F^\circ) + 459.6 \Rightarrow T(R^\circ) = 602.93$

2018/6/4

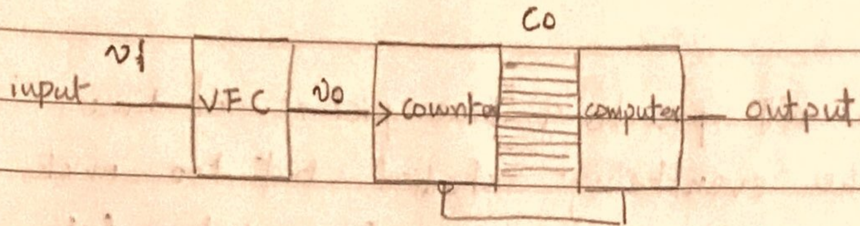
20 lecture

Examples:

if VFC has 5KHz/V and the reset time of the counter 0.02 sec what is the output if

a) the input 1.25 V

b) the input 2.43 V



Soluation

a)

νo = input * 5 KHZ/V = 6250 Hz

Co = νo * T = 125

b

νo = 2.43 * 5k = 12150 Hz

Co = 12150 * 0.02 = 243

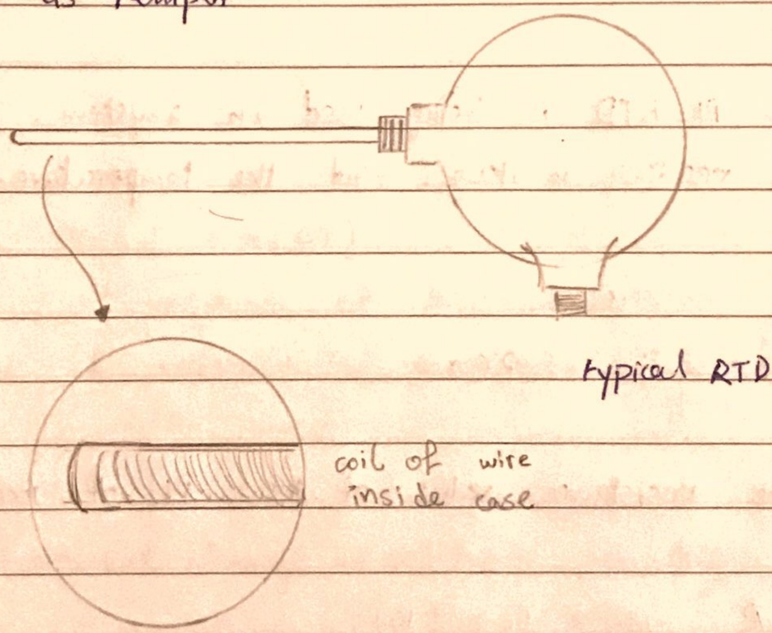
the equation of the system:

Co = νo * T = ν_i * rate * T

$$\nu_i = \frac{Co}{rate * T}$$

Temperature sensors give an output proportional to temperature, most temperature sensor have positive coefficient (PTC) (desirable) which that the sensor output gose up as the temperature goes up.
Some sensors have negative temperature coefficient (NTC) which means that the output goes down as the temperature goes up.

RTD : Resistance temperature detectors : is a temperature sensor based on the fact that metals increase in resistance as temper



A wire, such a platinum, is wrapped around a ceramic or glass rod (sometimes the wire coil is supported between two ceramic rods).

RTDs are available in different resistance, a common value being 100Ω. Thus, a 100-Ω platinum (Pt 100 RTD) has resistance of 100Ω at 0°C and has sensitivity of 0.39 Ω/C°

$$R = R_0 + \alpha \Delta T$$

Some characteristics

Sensitivity : dependent on its kind

Responce time : (0.5 ~ 5) sec الزمن الذي يستغرقه الحساس للاستجابة لتغير الحرارة

Range : Platinum (-100°C ~ 650°C)

Nicel (-180 °C ~ 300°C)

Examples:

- A 100-Ω Pt RTD is being used in a system. The present resistance reading is 110Ω. Find the temperature.

$R = 110 - 100 = 10\ \Omega$

$T = \frac{10}{0.39} = 25.6\ °C$

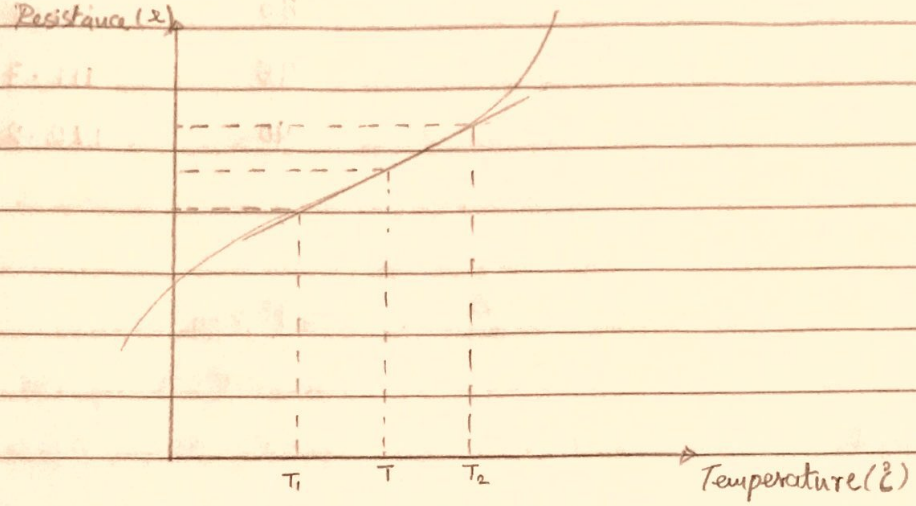
- Find the resistance value of 100Ω Pt of 100Ω at 10°C

$R = 100 + (0.39 * 10)$

$R = 103.9\ °C$

the advantage of RTD is being very accurate and stable. But its disadvantages are low sensitivity, relatively slow responce time, and high cost.

RTD linear approximation



$R(T) = R(T_0)\,[\,1 + \alpha_0 \Delta T\,]$ $\qquad T_1 < T < T_2$

resistance at temperature T_0

approximation of resistance at temperature T

$\Delta T = T - T_0$

α_0 = fractional change in resistance per degree

$$\alpha_0 = \frac{1}{R(T_0)} \cdot \frac{R_2 - R_1}{T_2 - T_1}$$

R_2 = resistance at T_2

R_1 = resistance at T_1

Ex:

Find the linear approximation of resistance versus temperature between 60F° to 90°F

T (°F)	R (Ω)
60	106.0
65	107.6
70	109.1
75	110.2
80	111.1
85	111.7
90	112.2

$$\alpha_0 = \frac{1}{R(T_0)} \cdot \frac{R_2 - R_1}{T_2 - T_1}$$

اول قيمة

اخر قيمة

قيمة المقاومة عند درجة الحرارة المتوسطة

$$\alpha_0 = \frac{1}{110.2} \cdot \frac{112.2 - 106.0}{90 - 60} = 1.8753\,m$$

check your answer

$R(60F) = 107.1$ error $= -1\%$

$R(85) = 112.3$ error $= 0.54\%$

RTD Quadratic approximation

$$R(T) = R(T_0)\left[1 + \alpha_1 \Delta T + \alpha_2 (\Delta T)^2\right]$$

where

$R(T)$ = quadratic approximation of the resistance.

$R(T_0)$ = resistance at T_0

$\Delta T = T - T_0$

α = linear fractional change in resistance with temperature

α_2 = quadratic fractional change in resistance with temperature

Ex:

Find the quadratic approximation resistance versus temperature between 60°F and 90°F

T(F°)	R(Ω)
60	106.0
65	107.6
70	109.1
75	110.2
80	111.1
85	111.7
90	112.2

Solution

$$106.0 = 110.2\left[1 + \alpha_1(60-75) + \alpha_2(60-75)^2\right]$$

$$112.2 = 110.2\left[1 + \alpha_1(90-75) + \alpha_2(90-75)^2\right]$$

بحل المعادلتين

$\alpha_1 = 1.8746\ m$

$\alpha_2 = -44.355\ \mu/(F)^2$

check your answer

$R(60) = 106.0\ \Omega$ error = 0%

$R(85) = 111.8\ \Omega$ error = -0.09%

Note the quadratic approximation provides a much better approximation of the resistance versus temperature

2018/6/11

22nd lecture

Thermocouple Tables

tables give the output voltage over a range of temperature in 5°C increments, the reference temperature is 0°C

The temperature in °C and the output in mV

in case the masured voltage does not fall exactly on a table value, we use interpolate

$$T_M = T_L + \left[\frac{T_H - T_L}{V_H - V_L}\right](V_M - V_L)$$

if the termperature does not found

$$V_M = V_L + \left(\frac{V_H - V_L}{T_H - T_L}\right)(T_M - T_L)$$

Ex: A voltage of 23.72 mV is measured with a type k thermocouple at a 0°C reference. Find the temperature of the measurement junction

$V_m = 23.72$ mV does not found in table so we use intrpolate

$$T_M = 570°C + \frac{575 - 570}{(23.84 - 23.63)m}(23.72 - 23.63)m$$

$$T_m = 572.1\ °C$$

Ex: Find the voltage of a type J thermocouple with 0°c reference if the junction temperature -172°c

$$V_M = -7.27m + \frac{-7.12 + 7.27}{-170 + 180}(-172 + 175)$$

$$V_M = -7.18\,mv$$

change of Table reference

it is possible to use tables with TC (Termocouple) has a different reference temperature by an appropriate shift in the table scale.

يعني أنه في حالة كان TC لديه مرجعية اخرى غير الصفر
فإن قيمة الجهد تساوي

قيمة الجهد عند المرجعية الجديدة = قيمة الجهد عند المرجعية صفر − قيمة الجهد للمرجعية الجديدة عند الصفر

Example $V_{30}(T) = V_0(T) - V_0(30)$